CALIFORNIA
AGRICULTURAL EXTENSION SERVICE

CIRCULAR 74

JUNE, 1933

Grain Sorghums in California

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Cooperative Extension work in Agriculture and Home Economics, College of Agriculture, University of California, and United States Department of Agriculture cooperating. Distributed in furtherance of the Acts of Congress of May 8, and June 30, 1914. B. H. Crocheron, Director, California Agricultural Extension Service.

THE COLLEGE OF AGRICULTURE
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

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HISTORY

The grain sorghums are of African and Asiatic origin and the first of them probably came to California some time after the middle of the last century. Evidence has been produced to prove that the durra or Egyptian corn varieties have been occasionally planted here since 1858, but it is certain that the crop did not become established as a staple in any part of the state until the early seventies.[3]

By 1870, organized irrigation in the San Joaquin Valley was well under way and there was a general influx of settlers into the newly organized land colonies throughout the valley. These small farmers, who were chiefly engaged in fruit, milk, and egg production, found themselves greatly in need of a summer grain crop to follow wheat or barley in a double cropping system, and also of a suitable grain to be grown between the rows of young trees and vines during the prebearing period. Indian corn, for various reasons, failed to meet these requirements, but in Brown and White durra (Brown and White Egyptian corn) crops were found which not only filled these needs satisfactorily but which were also highly productive and valuable stock and poultry feeds.

The first federal census to record the crop in California, that of 1899[4], credited the state with 20,218 acres; the second, that of 1909[4], with 44,308 acres; the third, that of 1919[5], with 167,814 acres; and the fourth, that of 1929[6], with 73,274 acres. Estimates for the intervening years to 1919 are wanting, but from those given it is evident that for the 30-year period indicated the crop had increased considerably in importance in California. The reasons for this doubtless are many, but among them two relating to improvements in the crop itself seem worthy of note in this place. First, during the early part of this period milo came to largely replace the less desirable durras; and second, toward the end of the period dwarf strains of milo better suited to the combined har-

[1] This publication replaces California Agricultural Experiment Station Bulletin 278, "Grain Sorghums," by B. A. Madson, issued April, 1917, and reprinted June, 1921.

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[3] For a review of the literature relating to the introduction of the various sorghums into California, see: Wickson, E. J. Senator Sorghum, a California pioneer. Pacific Rural Press 43:289–301. 1917.

[4] U. S. Dept. Com. Bur. of the Census, Thirteenth Census U. S. 5:620. 1910.

[5] U. S. Dept. Com. Bur. of the Census, Fourteenth Census U. S. 5:769. 1920.

[6] U. S. Dept. Com. Bur. of the Census, Fifteenth Census U. S. 2(1):92. 1930.

vester-thresher[7] came into general cultivation. These changes were instrumental in increasing yields and lowering production costs, and were therefore factors in the expansion of acreage.

During the period of depressed farm prices, from 1920 to the present, the acreage has averaged about 84,400, and the stability shown by the crop during this period as compared with the more erratic behavior of such competitive crops as cotton, beans, and sugar beets is due, in some measure, to a ready marketability coupled with low labor requirements and low production costs. By 1923 three new uniform strains of dwarf milo—Heileman, University Farm Select, and Meloland—had been distributed to growers, and by 1925 these had almost completely replaced the mixed and nonuniform dwarf milo strains which had preceded them. This in itself was an important step forward, but progress did not stop here. By 1926 Double Dwarf milo had begun to attract attention, and because of its conspicuous advantages had, by 1930, almost completely replaced all other milo strains in commercial plantings in all parts of the state.

These progressive changes have been responsible for the complete mechanization of production operations and for placing the crop on a par with the small grains in low production costs. Incidentally, they have necessitated some important changes in cultural practices and these are considered in the discussions which follow.

CLIMATIC AND SOIL REQUIREMENTS

The grain sorghums are well adapted to the warm interior valleys but do not produce well in the cooler coast and mountain districts. They are capable of surviving and producing grain with limited quantities of soil moisture, and are not seriously injured by extremely high temperatures or low atmospheric humidities during the flowering period. In these respects they surpass most other field crops, and therefore have come to be much relied upon in the interior valley districts.

When grown with a scant moisture supply (p. 7), the medium-textured soils of a loam type are preferable, because of their superior water-holding capacity, but with abundant water even the sandy soils are satisfactory. Extremely heavy soils of the clay or adobe type are not suitable because of the difficulty and expense of maintaining them in tilth, and large bodies of such soil in the Sacramento Valley rice areas, which are otherwise favorably situated with respect to water and climate, have, for the reasons stated, proven unprofitable for the production of the crop.

[7] Hereafter in this publication the single term "combine" will be used in place of "combined harvester-thresher."

SEED

Variety.—Seed of the particular variety or strain should be chosen which is best suited to the conditions under which the crop is to be grown, harvested, and disposed of. A discussion of the important varieties and their characteristics, which is intended to be of assistance in making such choice, may be found beginning on page 25.

Purity.—The seed should also be of a pure and desirable strain. The best seed inevitably tends to lose its purity through cross-pollination and through mechanical mixing with other varieties in the threshing and cleaning processes. To avoid losses through such deterioration the grower should obtain seed from a pure field grown in isolation from other varieties and not contaminated in the harvesting process. If such fields are not available locally, information regarding them in other localities may be obtained from the local county farm advisor or from the California Agricultural Extension Service, University of California, Berkeley, California. Occasionally small quantities of pure seed of staple varieties may be had from the Division of Agronomy, University Farm, Davis, California.

Quality.—The seed should also be uniformly bright, plump, and clean, and should sprout vigorously. Seed more than one year old, or that which has been artificially dried, or that which has been harvested in an immature or partly moldy condition, should be tested for germination prior to use. Artificial drying, however, when carefully done need not impair germination and in some cases in which the grain has contained a high moisture content when harvested the germination percentage has been improved by drying. Any citizen of California is entitled to not more than 10 free germination tests each year, and those wishing such service should take representative 4 to 8-ounce samples of the seed to be tested, enclose these separately in stout envelopes or small bags, and send by mail or prepaid express to the Seed Laboratory, State Department of Agriculture, Sacramento, California. Each sample should bear the following data: 1. Sender's identification mark. 2. Sender's name and address. 3. Name and address of person, firm, or corporation selling the seed. 4. Kind of seed. 5. Size of lot. 6. Date submitted. 7. All information contained on seller's label. 8. Kind of test desired (whether purity, germination, examination, identification, or complete).

Disease.—The crop is subject to attack by several diseases, but fortunately none of these have become a serious menace in California. All of the milos are resistant to the strains of common kernel smut found in California, and this no doubt accounts for the comparative freedom of

the crop as a whole from disease injury. The more common strain (physiologic form) of sorghum kernel smut attacks sorgos, broomcorn, kafir, and durra, but does not attack milo, hegari, or feterita. The next most common form attacks milo and hegari and also attacks those commercial varieties which are susceptible to the more common form. Under certain conditions, however, milo has been known to suffer serious losses from kernel smut, namely, when seed from a smutted crop has been planted upon infected subirrigated soils in the river districts. Losses up to 40 per cent of the crop have been known to occur under these conditions. In such cases it is probable, although not definitely proven, that the crop becomes infected, in part, from disease spores which winter over in the soil, and a change of crops for at least one year is recommended. The usual means of infection however is through disease spores adhering to the seed itself, and for this reason seed which has come from a field containing smutted heads, or which has passed through machinery which has recently handled such heads, should not be planted. If, however, such seed, or in fact any seed of unknown history, is to be planted, it should first be treated for smut, and similar treatment should precede the planting of clean seed on infected soils.

An effective treatment for kernel smut consists of a thorough dusting with the dry, finely pulverized dust of copper carbonate, at the rate of 3 to 5 ounces for each 100 pounds of seed. This should preferably be applied by means of ordinary wheat or barley-treating machinery; or in lieu of this in the hopper at planting time. This chemical, which adheres to the surface of the seed, goes into solution when placed in contact with moist soil, thereby tending to create a sterile zone about the germinating seed. This protects the seed from infection from the spores which may be present either on the seed itself or in the soil.

Certain varieties of sorghum, particularly the white-seeded ones, are subject also to the attack of common rot organisms present in nearly all soils, and these may destroy enough germinating seed to seriously impair the stand, particularly when germination is delayed because of adverse temperature conditions. The dusting treatment referred to is effective also in protecting the seed from such losses, but the chemical dust known as Ceresan has proven even more effective in insuring full stands under such conditions.[8]

[8] For further details see: Mackie, W. W. Diseases of grain and their control. California Agr. Exp. Sta. Bul. 511:1–87. 1931.

SOIL PREPARATION

Two general types of soil preparation are in use. The first of these—by means of a preplanting irrigation—is discussed under "Irrigation"; the second—without preirrigation—is here described. This latter system is limited to regions of abundant rainfall and is more commonly practiced in seasons of plentiful spring rain. For these reasons the practice is seldom possible in the central and southern California districts. The first requisite is that the land be deeply plowed during the fall or early winter months; the second that it be kept free from weeds during the winter; and the third that it be so worked during the early spring as to provide for the maintenance of fine tilth and surface moisture until planting time. The details of carrying out these operations will largely be determined by the season, the crop history of the land, and the soil type. In general a 6 to 10-inch plowing from November to January, followed by an occasional cultivation with a tooth or chisel-type implement during the rainy season to destroy weeds, in turn followed by an occasional shallow spring cultivation with a blade or cyclone cultivator, will, if opportunely and carefully executed, provide a deep, moist, well-settled seedbed with fine moist soil at or near the surface for the reception of the seed.

Such soil management as this provides for deep penetration and retention of rain, and under favorable conditions such as often prevail in the Sacramento Valley has made possible the production of profitable crops without irrigation either before or after planting.

PLANTING

Date.—The usual planting season extends from May 1 to June 15 in the Sacramento Valley; from April 15 to July 1 in the San Joaquin Valley; and from April 1 to August 15 in the Imperial Valley—or a planting range of approximately 45, 75, and 135 days, respectively, for the three valleys. Plantings in advance of these dates may suffer from unfavorable temperatures for germination, while those made later than these may not mature satisfactorily.

Although theoretically there is considerable latitude in the choice of planting date in these localities, circumstances often limit the possibilities more narrowly. When, for example, the crop is grown without preirrigation, it frequently becomes necessary to plant near or even in advance of the specified early usual limits in order to insure favorable moisture for germination; while, when it is grown as a second crop following small grains, planting of necessity must be deferred until near, or even after, the specified latest usual limits.

Yields have been little affected by variations in planting date within the usual range in the northern districts, but in the San Joaquin and Imperial valleys medium to late plantings, in most seasons, have been slightly more productive than earlier ones. In the southern districts late planted crops usually pass their critical "blooming" and "filling" periods during more favorable weather. May for the Sacramento Valley, June for the San Joaquin Valley, and July for the Imperial Valley are generally regarded as the most favorable planting months.

Spacing.—The factors which should determine spacing are variety, method of harvesting, and available soil moisture and fertility. That is to say, other things being equal, the scant-stooling durra (Egyptian corn) varieties require closer spacing than the free-stooling milos; fields to be combined should be more closely spaced than those to be hand-harvested; and plantings on comparatively dry or infertile soil should be given more space than those on comparatively moist, fertile soils.

The usual rate of planting for Double Dwarf milo intended for the combine and grown on productive, naturally moist land is from 4 to 5 pounds of seed per acre, planted in rows from 26 to 32 inches apart. The larger-growing Heileman milo under similar circumstances should be planted at the rate of from 3 to 4 pounds per acre, in rows 34 to 40 inches apart. The smaller-growing, light-stooling Dwarf White durra (Hoefling's Dwarf White Egyptian corn) under similar circumstances should be planted at the rate of from 6 to 7½ pounds per acre, in rows 26 to 32 inches apart. The old tall-growing White durra (Egyptian corn) is not adapted to combining and should be planted in widely spaced rows, 34 to 40 inches apart, in order to encourage the development of large heads and otherwise facilitate hand picking; but because of its scant-stooling habit it should be planted thickly in the row, or at the rate of from 4 to 5 pounds per acre.

Under such close spacings as these, individual plants are more crowded and react by stooling less, becoming more slender, producing smaller, more erect heads, and by ripening earlier and more uniformly; all of which is favorable to the more efficient use of the combine (fig. 1).

These close spacings and heavy rates of seeding, however, are advisable only upon naturally moist soils and are now employed only on subirrigated river lands or on the overflow lands of the Buena Vista Lake region in Kern County, and in other similar situations.

Surface-irrigated soils, upon which the moisture supply is less abundant, require wider spacings and less seed for the best results. Double Dwarf milo, for example, under such conditions should be planted at

the rate of 2½ to 3 pounds of seed per acre, in rows 28 to 34 inches apart; and Dwarf White durra at the rate of 4½ to 5½ pounds of seed per acre, in rows 28 to 34 inches apart. Similar adjustments should be made for the other varieties.

When grown as a dry-land crop without the aid of irrigation, still wider spacings and still less seed is recommended. Double Dwarf milo grown at Davis without irrigation, for example, has yielded more grain when planted in rows 7 feet apart than when planted in rows 3½ feet

Fig. 1.—A field of Double Dwarf milo on subirrigated soil, planted at the rate of 5 pounds of seed per acre, in rows 28 inches apart. Note uniform height, erect heads, and slender stalks.

apart, and the same variety grown in Tulare County, with only one irrigation applied prior to planting, has made better yields when planted at the rate of 1½ pounds per acre in rows 52 inches apart, and subsequently thinned to 6 inches in the row, than under closer spacings.

Under average dry-farm conditions, with limited supplies of soil moisture it is recommended that Double Dwarf milo be planted at the rate of ½ to ¾ pound per acre, in rows 60 to 72 inches apart; and Dwarf White durra (Dwarf White Egyptian corn) at the rate of 1 to 1½ pounds of seed per acre, in rows 60 to 72 inches apart.

The above recommendations are based upon the recent experience of growers with the new varieties under various conditions, supplemented by spacing experiments at Davis and in the Imperial Valley. As stated previously, the optimum distance between rows and between plants in the row is largely determined by the amount of soil moisture and by the habit of growth of the different varieties. Having determined these factors, the amount of seed required to plant an acre may be determined by the number of seed in a pound. An average recleaned sample of White

durra, either Dwarf or Standard, testing 58 pounds per bushel, contains approximately 13,945 seeds in a pound, while an average recleaned sample of either Dwarf or Standard milo testing 57 pounds per bushel contains about 15,759 seeds. Assuming that 75 per cent of the seed produces mature plants, the seed requirements for the different spacings recommended above have been calculated and presented in table 1.

TABLE 1

RECOMMENDED SPACING AND SEED REQUIREMENTS FOR DOUBLE DWARF MILO AND DWARF WHITE DURRA (DWARF WHITE EGYPTIAN CORN) UNDER DIFFERENT CONDITIONS OF SOIL MOISTURE

Variety	Soil moisture	Recommended distance between rows, inches	Recommended distance between plants in row, inches	Calculated number of pounds of seed required per acre
Double Dwarf milo	Subirrigation (abundant moisture)	26 to 32	4	4.1 to 5.0
Double Dwarf milo	Surface irrigation (medium moisture)	28 to 34	6	2.5 to 3.1
Double Dwarf milo	No irrigation (deficient moisture)	60 to 72	12	0.61 to 0.74
Dwarf White durra (Dwarf White Egyptian corn)	Subirrigation (abundant moisture)	26 to 32	3	6.2 to 7.6
Dwarf White durra (Dwarf White Egyptian corn)	Surface irrigation (medium moisture)	28 to 34	4	4.4 to 5.3
Dwarf White durra (Dwarf White Egyptian corn)	No irrigation (deficient moisture)	60 to 72	8	1.0 to 1.2

Covering.—The ordinary 2-row corn or bean planter, equipped with sorghum plates, is customarily used for planting. This implement is easily adjusted as to spacing of rows, rate of dropping, and depth of planting, and it is of importance to so adjust the planting depth that all of the seed is deposited in direct contact with moist soil. One to 2 inches for average-textured soils, or 2½ inches for light-textured soils are about the greatest safe planting depths; and if the surface soil is dry to these depths it becomes necessary to resort to furrowing in order to place the seed in contact with moist soil and yet not cover it too deeply. This is usually accomplished by means of small disks or shovels attached directly in front of the planter in such manner that the planter-shoe or disk runs in the bottom of a shallow furrow and deposits the seed directly in moist soil.

CULTIVATION

Row cultivation subsequent to planting is generally, but not always, necessary to insure satisfactory returns, although the manner and frequency of performing such work most economically is determined by local conditions. The first objects of cultivation are the destruction of weeds and the maintenance of good tilth. Most weeds may be destroyed more cheaply prior to seeding than afterwards, and for this reason one or more well-timed extra cultivations just prior to planting are often well repaid. When such preliminary work has been neglected, however, it often happens that weeds appear abundantly with the crop, and in part so situated in the rows that they are inaccessible to the cultivators. In such instances a light harrowing across the rows, just as the crop is emerging, may reduce the hand hoeing and row cultivation subsequently needed. This type of cultivation is most effective when the crop has been planted in shallow furrows. Following this, one or more cultivations may be needed to hold weeds in check or pulverize the soil following irrigation. Anything beyond this would be superfluous. Under the extremely narrow row spacing—26 to 32 inches—now frequently practiced, the plants meet between the rows and shade the ground so quickly that in many cases row cultivation may be dispensed with altogether.

Cultivators of the corn, bean, and beet types have all been used, but the first-named, because of its greater clearance, is preferable if more than one cultivation is needed. The choice of attachments should be determined by the work to be done. Duck-foot or weeder type tools may become injurious to soil texture, especially to heavy soils when wet, and should not be employed under such conditions. On the other hand, they are far superior to other types of equipment for combatting morning-glory, Johnson grass, and weeds of similar persistent character, and are not seriously injurious to the lighter soils even when wet. Many growers prefer narrow tools of the diamond-point or deer-tongue type for the first working, and blades or combinations of blades and teeth so arranged as to avoid root pruning, for the second working. Preceding irrigation, furrowing shovels may be used to better prepare the land for the distribution and absorption of water.

Hand hoeing is seldom profitable but may sometimes be needed in the early stages of growth to salvage the crop in badly infested morning-glory or Johnson grass spots.

Thinning of the stand may be effectively and cheaply accomplished by crossing the rows with a cultivator equipped with suitable duck-foot attachments when the plants are a few inches in height.

IRRIGATION

Irrigation before Planting.—A procedure has been described for the preparation of the land without the aid of irrigation, but conditions favorable to such preparation rarely exist in the important producing areas of central and southern California, and irrigation prior to planting must be resorted to. Furrowing the land, followed by a slow application of water, followed by plowing and cultivation, are the usual steps in preparing the land for planting. Irrigating in basins, free flooding from contour ditches and subirrigation, all are occasionally employed as means of applying water under special conditions. The aim of all preplanting irrigation, however, regardless of the means employed, should be to moisten the soil as uniformly as possible to a depth of at least 3 feet, and to 4–6 feet or more where possible, in order to insure a vigorous early development of the crop. Usually the preplanting irrigation is more easily applied than later ones and may save one irrigation later in the season if thoroughly done.

Irrigation after Planting.—The amount, frequency, and method of applying water to the growing crop must also be determined by circumstances. The most reliable guide in this matter is the appearance of the crop itself, which should be thrifty and vigorous at all times. A single thorough preplanting irrigation which has penetrated to a depth of 8 feet or more should insure a crop without further irrigation, upon a clay or clay-loam soil. In dealing with less retentive soils of a loam or sandy-loam type, one or two more irrigations may be advisable, while in the case of sandy soils two or more postplanting irrigations may be necessary to produce a satisfactory yield. To be profitable, however, the cost of such later irrigations must not exceed the value of the increased yield induced by it. In certain of the deep-well areas of the San Joaquin Valley the cost of irrigation, including pumping, ditching, furrowing and cultivation, may approach or actually exceed the value of such yield increments, and here the crop is grown in some cases with a single thorough preplanting irrigation. With such limited moisture, however, it has been found desirable to widen the space between the rows to 52 inches or more and then to thin the plants to about 6 inches in the row. Under such conditions a light, short, early-maturing crop of Double Dwarf milo, well adapted to the combine, has been cheaply produced. For a discussion of the relation between moisture supply and spacing see page 8.

With less costly water it will usually prove profitable to irrigate once or in some cases twice following planting, but in general these should

not be continued after the heads have appeared. Usually one thorough irrigation, when the crop is from 12 to 18 inches in height, will suffice; but a second one, two or three weeks later, may become desirable under very dry conditions. Irrigation after the heads have appeared is generally inadvisable because it delays ripening, induces suckering, and may cause lodging.

Water may be applied to the growing crop either in previously prepared large checks or in row furrows. The former is suitable for level land under a plentiful supply of water such as is to be found in the Imperial Valley, while the latter has the advantage of better serving unleveled areas and of utilizing more economically small heads of water.

Subirrigated soils of the Stockton delta and adjoining districts have been utilized to an increasing extent for the production of the crop in recent years. Here, with an abundance of moisture and warm summer temperatures, the crop develops vigorously and yields well; but because of the difficulty of draining such soils, particularly those of a peaty character, there has been difficulty in ripening the crop sufficiently early for the use of the combine in the fall. Experience in this district has taught that earlier maturity may be induced by very early draining of the land—some time in advance of heading—and by planting early and very thickly in order to take up soil moisture as rapidly as possible. One successful producer in the region practices fall plowing, the seeding of Double Dwarf milo at the rate of 4 to 5 pounds per acre in 28 to 32-inch rows early in May, and draining as completely as possible just prior to the appearance of the first heads. By such procedure very uniform crops well adapted to the combine have been produced. Because of a relatively high moisture content, however, it has usually been necessary to dry the threshed grain prior to storage in order to prevent heating and molding.

HARVESTING

The Evolution of Harvesting Methods.—The grain sorghums have been adapted slowly to modern harvesting methods. From 1875 to 1915, hand-heading was the prevailing method, although attempts had been made to adapt the combine to the crop from 1900 onward. Such attempts were never entirely successful, however, because of the tall, uneven, and bulky nature of the crop, which caused heavy harvesting losses. Consequently, the more primitive hand method prevailed even though the cost was higher than for the harvesting of an equivalent amount of barley under the combine system.

During this period, however, progress was being made. An occasional light crop of Standard milo, Standard White durra, and of Standard

Brown durra was combine-harvested with fair success. Single Dwarf milo made its appearance in California about 1910, and Heileman, University Farm Select, Meloland, and other uniform strains were later distributed. As a result of this, light crops were efficiently and cheaply handled with the combine and larger acreages were planted with this in view. Heavy crops produced on moist soils were still too bulky and tall for the combine, and for a time various types of headers, strippers, and binders came into competition with the hand method for the harvesting of such crops. Then, in about 1925, the coming of the still shorter Double Dwarf variety of milo gave added impetus to the combine method. This variety, because of its extremely dwarf and uniform habit, could be as efficiently combined as wheat or barley, even when grown on moist soils. In fact, it offered a complete solution to the mechanical difficulties previously encountered and for this reason had almost completely replaced all antecedent milo varieties in the state in less than five years, or before 1930.

In 1929 the Hoefling strain of Dwarf White durra (Dwarf White Egyptian corn) was put on the market and this proved so superior to the old durra varieties for combine-harvesting that by 1932 it, too, had largely replaced its parent form and another obstacle to the use of the combine had been removed.

Other difficulties, however, now presented themselves. Grain originating on moist soils, although now easily combined, frequently contained too much moisture to keep without deterioration in sacks or in bulk. Several possible solutions of this difficulty presented themselves. Conrad and Stirniman proposed a system of root cutting[9] by means of which the mature plant was severed from its root system at from 5 to 7 inches below the crown, following which the standing plant, including the grain, dried rapidly enough to be safely combined about 10 days later.

A second proposal for overcoming excess moisture was that of windrowing the crop and then after a period of drying in the windrow to thresh it with a combine equipped with a pick-up device similar to those employed for beans and rice.

The third method, and that which has come to prevail over the other two, is that of artificially drying the threshed grain following harvest. With due care, even very moist grain may be held in the sack for several days without deterioration, during which time it may be sent to one of the commercial drying plants. This method eliminates one field operation and is more expeditious and cheaper than the others.

[9] For a discussion of the root-cutting system and other harvesting methods for grain sorghums, see: Conrad, J. P., and E. J. Stirniman. Improved methods of harvesting grain sorghum. California Agr. Exp. Sta. Bul. 477:1–41. 1929.

Progress, however, did not end here. Experience with Double Dwarf milo soon taught the advantages of closer spacing. By such practice it has been possible to produce crops which ripen earlier, more completely, and more uniformly than formerly, and which present the general appearance of a level floor of heads much like wheat or barley at maturity (fig. 1). Close spacing, however, is advisable only under certain conditions, a discussion of which may be found beginning on page 8.

Fig. 2.—A combined harvester-thresher at work in a field of Double Dwarf milo.

Use of the Combine.—As a result of the above-mentioned improvements in variety, changes in cultural practices, and provision for artificial drying, all of the extensive grain-sorghum acreages of the state are now harvested by means of the combine (fig. 2). Machines of all makes, both large and small, have been satisfactorily adapted to the work with minor adjustments and alterations. Under favorable conditions no changes in the cutting mechanism have been found necessary, but in dealing with irregular stands the following have proven helpful: First, by providing extra wide reel slats, increasing the height of the platform back and closing the outer end of the platform, it has been possible to reduce losses due to the hooking of heads on the slats and the "throwing" of such heads clear of the draper. Second, by substituting a special stripper form of sickle guard for the ordinary one, and a small iron reel for the ordinary wooden one, and arranging these in such manner that the heads are drawn downward through the long guards and cut with short stalks, irregular and partly "down" stands may be handled

with fair efficiency. Both of the above alterations came into use while the Heileman type predominated and are now seldom necessary. Likewise, badly lodged or down stands are seldom met with under present day conditions of culture, but when they are a special patented type of guard known as the Hampton sickle bar, which permits of cutting close to the ground, and which does not clog easily, has been found helpful.

Desirable changes within the separator are in part the same as those formerly made in preparing the stationary thresher for handling grain-sorghum heads and are six in number: first, the speed of the cylinder is reduced approximately 35–50 per cent below that used for threshing wheat, but the speed of the other parts of the machine is maintained through the use of special pulleys or sprockets; second, the removal of one or two rows of concave teeth and the lowering of the remaining concaves if necessary to prevent cracking; third, the clearance between cylinder and concave teeth must be uniform and equal to prevent cracking; fourth, the substitution of special sorghum-straw racks to handle the more bulky material if necessary; fifth, the attachment of a piece of sheet metal over the space between the chaffer and the tailboard if necessary to prevent the delivery of excessive quantities of "ground-up" green matter into the tailings or return elevator, and to carry the tailings over the tailings auger trough and out of the machine. If this fifth change is not made, the tailings will go into the return elevator and thus be carried to the cylinder and finally, by this return process, they will be reduced fine enough to pass through the sieve into the grain auger and delivered into the grain sacks. This adjustment is helpful when working in "green" fields by reducing the danger from the heating of the grain in the sack and also in reducing the rate at which the shoe becomes loaded and its efficiency reduced. Sixth, the increasing of the wind blast and the use of a nonchoke screen in the shoe both serve to prevent clogging due to excessive bulk, especially when dealing with irregular or down stands.[10]

ARTIFICIAL DRYING

By means of a simple test which may be quickly made at any of the federal-state grain-testing laboratories, by some of the grain dealers, or by some of the county farm advisors, the approximate moisture content of threshed grain may be determined. This, expressed in terms of percentage of the total weight of the grain, has been found to range from as low as 10 for grain produced on "dry land" to as high as 30 for grain

[10] For further details see: Martin, J. H., L. A. Reynoldson, B. E. Rothgeb, and W. M. Hurst. Methods of harvesting grain sorghums. U. S. Dept. Agr. Technical Bulletin 121:1–35. 1929. Also, Conrad, J. P., and E. J. Stirniman. Improved methods of harvesting grain sorghum. California Agr. Exp. Sta. Bul. 477:1–41. 1929.

produced on moist land. If moisture is in excess of 15 per cent there is danger of the grain going out of condition if held in the sack or in bulk for more than a few days following harvest, and such grain therefore must be artificially dried if it is to be preserved. Before the general use of the combine, when heads were always dried prior to threshing, there was little need for such treatment, but now since the major portion of the crop is combined, the practice of drying has become general. The first drying plant to serve the purpose in California of which we have knowledge was erected in Stockton in 1916, and since that time others, conveniently situated to serve not only grain sorghum but other crops in need of such treatment, have appeared in various parts of the state. So far as the grain sorghum crop is concerned these establishments now serve as an auxiliary to the combine. In favorable seasons they have been little used, while in others less favorable a considerable part of the crop becomes dependent upon them for preservation. Such commercial plants have a capacity of from 40 to 100 sacks per hour, and charges during the 1932 season were from $2.00 to $3.00 per ton, depending chiefly upon the amount of moisture present.

An artificial drier recently installed on the ranch of a Sacramento Valley rice grower at Trowbridge for the drying of rice has also been successfully used for drying milo, and at a lower cost than that given above. Bates and Bodnar[11] who conducted studies on the drying of milo at this plant in 1930, think that the farmer who has an average of more than 3,000 sacks of milo per year to dry could probably afford to install his own drying plant.[12] Drying has the effect of raising the test weight per bushel and tends to raise the commercial grade and value of the grain.

DOUBLE CROPPING

Natural Requirements.—Double cropping, or the growing of two crops in sequence on the same land during a twelve-month period, has long been practiced in certain parts of the state, and the grain sorghums, since their introduction, have been grown to some extent in this way. Such practice is only possible under certain favorable natural conditions, and is then much more effective in certain districts than in others.

Requisite to the success of such practice are: a mild winter season followed by a long warm summer season, a friable and well drained soil,

[11] Personal communication from E. N. Bates and G. P. Bodnar, Office of Grain Investigations, Bureau of Agricultural Economics, U. S. Department of Agriculture.

[12] For further particulars regarding construction and operation of this plant see: Bainer, Roy. Harvesting and drying rough rice in California. California Agr. Exp. Sta. Bul. 541:18–23. 1932.

and an abundant well controlled water supply. Climate, however, has been the most important of these factors. In the Sacramento Valley, a relatively cool climate retards the development of both summer and winter crops to such an extent that growth cycles tend to overlap, leaving scant time for the preparation of the land between crops. The practice is possible there, but for the reason stated has not been extensively employed. Experience at the University Farm at Davis indicates that milo may be satisfactorily grown for ensilage following barley, providing milo planting may be completed prior to June 15. In the warmer San Joaquin Valley, on the other hand, no such difficulty exists, for the reason that the growth period of both summer and winter crops is appreciably shortened and the summer season is considerably longer. Climatic conditions are also favorable to the practice in the Imperial Valley, and this, together with extensive areas of level productive soil, under a cheap, plentiful and well-controlled water supply, has conspired to make that valley the most extensively double-cropped region of the state. In recent years, an average of about 15,000 acres of Double Dwarf milo alone has been produced in that valley as a second crop following barley, wheat, or truck crops.

Suitable Crops.—Barley and wheat, particularly the earlier varieties of these, are the most satisfactory of the winter field crops for large-scale double cropping, although oats, peas, horse beans, and other winter-growing annuals have been occasionally employed. Double Dwarf milo and Dwarf White durra (Dwarf White Egyptian corn) are the most satisfactory of the summer field crops for such practice, particularly for large-scale production. Various kinds of field beans may also be used in this way but have generally proven less satisfactory than the grain sorghums.

Soil Preparation for the Winter Crop.—The winter crop, usually barley, should be planted from September 15 to December 30, depending chiefly upon season and locality, the earlier possible dates generally being preferable to the later. If the preceding crop has been a grain sorghum, the stubble remaining from this should have been removed by pasturing or otherwise prior to plowing, but beyond this no special soil preparation is required except in very dry districts such as the Imperial Valley, where it is necessary to irrigate prior to planting in order to insure an early start. Barley planted in this way should be ready to harvest from April 15 in the south to as late as June 15 in the north, depending to some extent upon season and soil. Following harvest, preparation of the land for the succeeding crop should begin.

Soil Preparation for the Summer Crop.—The preparation of a satisfactory seedbed for grain sorghum or for any summer crop which is to follow barley in a double-cropping system is a more exacting process because such seedbed, to be effective, should not only be deep, moist, and well settled to the bottom, but it should also be free of clods and rough stubble, which are more objectionable here than in the case of a winter crop. For this reason a heavy barley stubble should either be removed or thoroughly chopped prior to plowing. In the Imperial Valley, with its longer season, this may be most economically done by pasturing, but in the northern districts other less time-consuming methods of disposal must be resorted to. Burning has often been employed in the San Joaquin Valley as the cheapest, most rapid, and effective method, but this is inadvisable as a regular practice because of its ultimate injurious effect upon the soil. A stubble of medium or light bulk may be suitably prepared for plowing by crossing it in two directions with heavy cutaway type disk, but a very bulky stubble, if neither pastured nor burned, should be mowed and raked and removed from the field prior to plowing.

Following stubble disposal, the common practice is to "plow dry," irrigate in furrows or checks, and finally cultivate to good seedbed condition preparatory to planting. This is a simple and direct procedure but one which is limited in its application to clean land of medium to light texture. Heavy soils merging on the clay or adobe types do not yield well to dry plowing, while land in heavy stubble is also unsuited to such treatment. Under either circumstance then it becomes desirable to reverse the order of operations by first irrigating and then plowing, following which three possible courses, each possessing merit under special conditions, present themselves. These are, including the preliminary irrigation: (1) irrigation, plowing, cultivation, and planting; (2) irrigation, listing or furrowing, followed by planting in the bottoms of the furrows; and (3) irrigation followed by plowing, followed by a second irrigation, followed by cultivation and planting. The first of these methods is well suited to comparatively clean and workable soils, while the latter two are generally reserved for less favorable conditions. The second—irrigation followed by deep furrowing, followed by planting—provides an inexpensive means of planting below clods and trash on rough unprepared land and has been successfully employed on deep soils under a plentiful supply of water. The third, providing for two irrigations, one before and one after plowing, is an effective means of consolidating a trashy seedbed, such as is left following the disking down of a heavy barley stubble, but it is seldom used because of its costliness.

INTERCROPPING

Grain sorghum has been extensively employed as an orchard and vineyard intercrop in California, and has maintained its popularity for such use in competition with other field and truck crops largely because of its general farm utility, market stability, and simple cultural requirements.

The crop is known to exert a temporary depressing effect upon soil productivity, but this has never been regarded as of serious consequence in the case of young trees and vines among which it is grown. Annual crops following sorghum may suffer from nitrogen deficiency, particularly on nitrogen-deficient soils, but the effect is temporary and may be corrected through the use of nitrogen fertilizers. In the case of young trees and vines sorghum rarely exerts a noticeably injurious effect, but should such effect become apparent this too may be overcome through the application of small amounts of nitrogenous fertilizers in basins around the trees.

Sorghum also makes a comparatively heavy draft upon soil moisture, and for this reason and also because of its shading effect should not be grown nearer than three feet from the young trees, and should not be planted at all unless there is a sufficient irrigation supply for both crops.

Double Dwarf milo has led all other varieties as an intercrop in California because of its dwarf, compact habit, which imposes minimum obstacles to the care of the young trees. Dwarf White durra (Dwarf White Egyptian corn), however, possesses similar advantages, and in addition ripens earlier. The latter is particularly well adapted to the northern Sacramento Valley, where it has been used to some extent as an orchard intercrop in preference to Double Dwarf milo.

Following the harvest of grain sorghum as an intercrop, a winter covercrop such as vetch or annual yellow sweet clover, *Melilotus indica,* may be planted with benefit to the soil; but such practice is dependent upon an available water supply for irrigation prior to both sorghum and vetch planting. Under average conditions the sorghum would be planted in May and harvested in September, and the vetch or sweet clover planted in October and turned under in March.

FORAGE USES AND VALUE

The milos and durras are less productive and less valuable as forage crops than the sorgos, including such varieties as Honey, Orange, and the Ambers, and for this reason are seldom planted exclusively for forage production. All of the grain sorghums and sorgo varieties ex-

cepting Double Dwarf milo and Dwarf White durra (Dwarf White Egyptian corn) are objected to because of their tendency to lodge and interfere with harvesting operations, and many stockmen have chosen to grow Indian corn, usually King Philip Hybrid, in preference to them because of this, and also because of the higher nutritive value of corn silage. They—the grain sorghums—do possess distinct forage value however and are occasionally converted into silage or fodder, or are pastured with satisfactory results.

Silage.—To make silage of good quality the milos should be allowed to advance in maturity until the seed is well hardened, but the durras, which are less succulent, may safely be cut in the "stiff dough" without danger of souring or spoiling. Small acreages are customarily cut for silage by hand or with a horse-drawn sled-cutter, but larger ones may be more economically handled by use of the row binder, which ties the crop in bundles of convenient size for handling. After chopping, the material should be spread in the silo in such manner that the center is maintained at a higher level than the sides during the filling process, and if the crop has been sufficiently matured when cut there will be no necessity of applying water or of tramping. If cut slightly green and allowed to remain in the bundle for any length of time there is always danger of souring.

Grain sorghum silage is well liked by sheep and dairy and beef cattle, but is less valuable as a feed than that made from a good, yellow flint corn such as King Philip Hybrid. There is always some loss in feeding because of a portion of the seed remaining undigested.

Fodder.—Numerous trials have proven that silage is the most valuable and efficient form in which the crop may be preserved, and yet, since it is not always possible to make silage, a portion of the crop may be converted into cured fodder (the whole plant with the head attached) and fed during the winter season. To prepare grain sorghum in this form the crop should be allowed to advance in maturity until it is dry enough to bind without souring or molding. This will vary greatly under different conditions but will usually mean "soft dough" for the durras and "stiff dough" for the milos. If, on the other hand, the crop is cut with the mower and turned frequently in the swath and windrow, it may be cut at a still earlier stage of development, although this is not generally advisable because of possible loss of quality and added expense. Well cured fodder may be preserved for winter feeding in large shocks, or stacks in the field, or in barns, and in such form will serve to maintain stock cattle, work animals, or sheep during the winter with little or no supplmentary feed, although protein supplements are de-

sirable even for wintering, especially for young animals. Shredding of fodder prior to feeding has been found to reduce waste but has proven unprofitable except in large-scale operations.

Stover.—Stover is that portion of the crop remaining after grain harvest, and while this possesses forage value it is usually not sufficiently valuable to warrant cutting, curing, and storing. In California such material is customarily utilized as pasturage, and when supplemented with a small amount of concentrated feed or alfalfa hay has served to carry sheep and cattle in good condition well into the winter. On moist soils there is generally some green second growth from the stubble which will be eaten first, following which cattle will eat the fine stalks and sheep will consume practically the entire residue excepting the crown itself and that portion which is lost through trampling in the mud.

Soiling and Pasturing.—The grain sorghums are used only incidentally for green feed because of the superiority of Sudan grass and the sorgos. They do possess distinct value as green feeds, however, and may be so utilized with less danger of bloating or poisoning than in the case of sorgo. There is no danger of bloating on Sudan grass pasture.[13]

Poisoning.—The probability of prussic acid poisoning from the pasturing of grain sorghums or Sudan grass in California is very slight. In fact, no authentic case of such poisoning has yet been reported to the Experiment Station. Prussic acid has been known to accumulate in dangerous quantities in both Johnson grass and sorgo varieties following periods of severe drouth or light frosts, particularly in the early stages of growth. When pasturing plants of this character, it would therefore be well to test the field by first turning in an animal of little value, and since the action of the poison is swift a few hours should suffice for this test. As an added precaution, valuable stock should be given a light grain ration before being turned into a suspected field.

Slow curing of poisonous forage destroys most of the poisonous substances and ordinarily renders the crop safe for feeding.

Treatment of Poisoned Stock.—The successful treatment of human beings poisoned with potassium cyanide has recently been reported by Geiger,[14] Brooks,[15] and others. In the case reported by Geiger 50 cc of a 1 per cent sterile aqueous solution of methylene blue (methylthionine

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[13] For further details on the use of sorghums for forage, see: Vinall, H. N., and R. E. Getty. Growing and utilizing sorghums for forage. U. S. Dept. Agr. Farmers' Bulletin **1158**:1–32. 1930.

[14] Geiger, J. C. Cyanide poisoning in San Francisco. Jour. Amer. Med. Assoc. **99**:1944–1945. Dec. 3, 1932.

[15] Brooks, M. M. Methylene blue as an antidote for cyanide and carbon monoxide poisoning. Jour. Amer. Med. Assoc. **100**:59. Jan. 7, 1933.

chloride U. S. P.) was used. According to Haring,[16] the intravenous dose for a 1,000-pound cow should be 1,000 cc of a 1 per cent sterile aqueous solution of methylene blue U. S. P.

The following statement regarding the treatment of poisoned animals is quoted from Haring:[17] "The rapid action of prussic acid often gives no time for treatment, but in cases of poisoning due to the presence of prussic acid in the forage the symptoms do not develop so quickly as with the free acid, and efforts to relieve the animals may be of some value. Cattle or sheep which are down in the hot sun should be protected by an improvised shade. If the ground is sloping, the head should be turned up hill, care being taken not to interfere in any way with respiration. When bloating occurs, it should be relieved by puncturing the paunch with a trocar and canula, or a sharp knife, thrust through the left side at a point a hand's breadth in front of the hip bone.

"The subcutaneous administration of atropine sulphate and other stimulants in doses suited to the size and species of the animal is recommended. Inhalations of ammonia may also be used for the same purpose.

"Hydrogen peroxide has been recommended by toxicologists as an antidote. The dose for a cow should be at least a pint mixed with an equal quantity of water.

"In cyanide plants and gold mines, using the cyanide process, it is customary to keep on hand prussic-acid antidote outfits for human use, consisting of two reagent bottles and a drinking glass. Any stock owner can prepare at small expense a similar outfit for use on farm animals.

"Directions for Preparing Johnson-Grass Antidote Outfit:

"Bottle No. 1.—Select a strong bottle of at least a quart capacity, having a long neck suitable for use in drenching cattle. Place in this bottle one pint of water and one ounce of sodium carbonate. (Ordinary washing soda will do.) Keep tightly corked.

"Bottle No. 2.—This should contain one-half ounce of iron sulphate (copperas) dissolved in a pint of water. Keep tightly corked.

"Directions for Use of the Antidote Outfit.—When needed, pour the contents of Bottle No. 2 into Bottle No. 1, shake and administer immediately. A cow should receive the entire quart of mixture. For a sheep one-half pint of the mixture would be sufficient. This antidote would be valuable also for cases of Paris green or other arsenical poisoning. In case it seems desirable to have enough antidote on hand for several head of cattle, larger amounts of the solutions may be stored in demijohns or

[16] Haring, C. M. Personal communication.

[17] Haring, C. M. Precautions against poisoning by Johnson grass and other sorghums. California Agr. Exp. Sta. Unnumbered circular.

large glass carboys, but *not in metal containers.* When needed, empty both reagents into a pail and administer to each animal from the mixture.

"Attempts to administer the drenches should be cautious to avoid choking, as the animal may be unable to swallow. The antidote may be given to cattle and sheep through a canula inserted into the paunch through the left side in the manner used for relieving bloat.

"Glucose, corn syrup, and molasses are said to be beneficial to cattle in case of prussic-acid poisoning and may be given in large quantities. Their administration, however, should not take preference over the antidotes previously mentioned."

Intravenous injection of methylene blue as above mentioned is probably the most effective of known antidotes for cyanide poisoning.

GRAIN USES, VALUE, AND YIELDS

In the early years of its production in California the crop was largely fed on the farms where it was grown, but with the rapid expansion of acreage following the mechanization of its production there has been a growing surplus to dispose of. That portion of the crop which remains on the farm is now fed chiefly in the production of eggs, pork, milk, beef, and mutton, but the surplus is used almost exclusively in the manufacture of prepared poultry feeds. This surplus, however, has been sufficient to meet only a portion of the California demand and the deficiency has been supplied largely through importation from Texas, Oklahoma, New Mexico, Kansas, and occasionally from the Orient. The amount of this crop imported into California each season varies widely and usually reflects the relative supply and price levels of all feed grains both in California and the Middle West. The domestic importations have consisted largely of milo and kafir and those from the Orient of kaoliang, while the California crop has been chiefly milo with a comparatively small amount of durra (Egyptian corn). The last named variety has been available in quantity only in California and is the most valued of all varieties for poultry feeding.

Numerous tests have shown that the different grain sorghum varieties resemble each other closely in chemical composition, digestibility, and palatability, and that they approach but do not quite equal Indian corn in their nutritive effects. Because of the hardness of the seeds, however, it is usually necessary that the grain be ground prior to feeding in order to obtain the most satisfactory results. Like Indian corn, they require supplementary feeds rich in protein. For poultry, protein is usually supplied in the form of a mash, while for other classes of stock this may usually be most economically supplied in the form of alfalfa. In the

absence of alfalfa, however, cottonseed meal for cattle and sheep, tankage or skimmed milk for hogs, and bran or shorts for horses, each with its appropriate succulents and roughage have satisfactorily supplied this requirement. In addition to these, there are other feeds which may serve equally well in balancing the grain-sorghum ration, the choice usually being determined by the quality and cost of the material itself and upon the class and age of the animals to be fed.[18]

Grain yields of milo and durra (Egyptian corn) which may reasonably be expected under favorable natural conditions and good management are as follows: on dry land, 1,000–2,000 pounds per acre; on surface-irrigated land, 2,500–3,500 pounds per acre; and on subirrigated land 3,500–4,500 pounds per acre. Higher yields are possible and are often produced under the conditions specified.

OFFICIAL GRAIN STANDARDS

Five different grades, including a sample grade, have been established for the grain sorghums by the federal government, and buyers and shippers are privileged to call upon licensed grain inspectors at the principal shipping points and markets to have the official grade of any shipment officially established. These grades as promulgated by the Secretary of Agriculture and published in the Handbook of Official Grain Standards, dated Washington, D. C., 1929, are given in table 2.

VARIETIES

Yellow Milo.—The geographic origin of milo is unknown but all available evidence points to the conclusion that it came to us from northern Africa, where several varieties of similar character are now in cultivation. The exact time, place, and manner of the first American importation are also unknown, but it first began to attract attention in the South Atlantic states soon after 1880, and had reached Texas and California by 1890. The original stock of this variety consisted of a diverse mixture of types. It was poorly adapted to combine-harvesting, but because of its superior productiveness and seed-holding power it early began to compete successfully with the durra (Egyptian corn) varieties which had been introduced into California at least sixteen years earlier.

[18] For further details see: Ball, C. R., and B. E. Rothgeb. How to use sorghum grain. U. S. Dept. Agr. Farmers' Bulletin 972:1–18. 1918. Also: Scott, G. A. The feeding of grain sorghums to livestock. U. S. Dept. Agr. Farmers' Bulletin 724: 1–15. 1916.

TABLE 2

GRADE REQUIREMENTS FOR GRAIN SORGHUMS

Grade No.	Condition and general appearance	Minimum test weight per bushel	Maximum limits of—						
			Moisture content	Damaged kernels		Other grains		Foreign material and cracked kernels	
				Total	Heat damaged (grain sorghums or other grains)	Total	Non-grain sorghums	Total	Sand, dirt, and finely broken kernels
		Pounds	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1*	Shall be cool and of natural odor, and of good color	55	14	2	0.2	3	1	3	0.5
2	Shall be cool and of natural odor, and may be slightly discolored	53	15	5	0.5	5	3	6	1.0
3	Shall be cool and of natural odor, and may be discolored	51	16	10	1.0	7	5	10	2.0
4	Shall be cool and may be musty, sour, or badly discolored	49	18	15	3.0	10	10	15	3.0

* Grade No. 1 for white kafir and white durra shall consist of 95 per cent or more of white kernels, including other classes and nongrain sorghums. Grade No. 1 for yellow milo shall consist of 95 per cent or more of yellow kernels, including other classes and nongrain sorghums.

Sample grade: Shall be white kafir, kafir, yello milo, milo, white durra, durra, feterita, darso, freed sorgo, brown kaoliang, schrock kafir, or shallu, respectively, which does not come within the requirements of any of the grades from No. 1 to No. 4, inclusive, or which has any commercially objectionable foreign odor, or is heating, hot, or otherwise of distinctly low quality.

Standard Yellow Milo.—Purification of the crop began soon after its introduction into Texas and California, and by 1905 a more uniform and slightly shorter-growing strain, 6 to 8 feet in height, known as Standard milo, was being tested at the western experiment stations. This possessed distinct cultural advantages over the original stock and by 1910 had not only largely replaced the old milo type but had also superseded the durras (Egyptian corns) as the dominant California variety. But its ascendency was of brief duration, for by 1925 it in turn had been replaced by various strains of Single Dwarf milo.

Single Dwarf Yellow Milo.—The exact genesis of Single Dwarf milo is also unknown, but all available evidence points to the conclusion that it is a mutant from Standard milo, which first appeared in Oklahoma in about 1900. The earliest record of its distribution was that by the Barteldes Seed Company of Lawrence, Kansas, in the spring of 1906. The first field to come to the attention of experiment station officials was that on the farm of Judge J. F. Bradley, in Hull County, Texas, in 1906, and the seed from this crop was given wide distribution in 1907. Following this it soon became the dominant variety in the Texas-Oklahoma region and had penetrated California by 1910. The first seed to reach California came through commercial channels and the resulting crops exhibited great irregularity because of mixture with Standard milo. In 1917, the California Agricultural Experiment Station began its purification and in 1921 began the distribution of a uniform dwarf strain under the name University Farm Select. Several other isolations of dwarf types were also made at about this time. In 1916 a group of 4-H Club members in Glenn County, working under the direction of Assistant State Club Leader R. M. Hagen, began the selective improvement of milo, and after three years of effort turned over their material in 1919 to the late W. H. Heileman, then farm advisor for Glenn County. Heileman continued the work of the Club, and in about 1922 began the distribution of a uniformly dwarf strain which subsequently became known as Heileman milo. A third strain, selected from Heileman or University Farm Select by L. G. Goar, of the University of California Imperial Valley Experiment Station, was widely distributed in the Imperial Valley subsequent to 1922 under the name Meloland. For a time the selective improvement of milo became popular and soon the Stannard's and the Avondale dwarf strains appeared on farms in the Salt River Valley of Arizona, and other similar strains in California. All of these closely resembled or were identical with the above-mentioned varieties, and apparently either were reisolations of the original Oklahoma mutant, were new dwarf mutants from Standard, or were hybrids

between these and Standard milo. They were so similar in fact that their identities were not maintained and soon all were referred to as Heileman.

Dwarf milo strains resemble Standard milo closely in all respects except height, which is only 4 to 6 feet under conditions which would cause Standard to attain a height of from 6 to 8 feet. They are slightly more productive under average California conditions than any other grain-sorghum variety, and are superior to the durras (Egyptian corns) for forage purposes. Their chief defects have been tall growth and tendency to lodge when produced under conditions favorable to high yields.

Double Dwarf Yellow Milo.—The origin of Double Dwarf Yellow milo is unknown, but genetically it appears to be a double recessive for height and may possibly have originated either as a mutation from Single Dwarf milo or as a recombination product of two different dwarf mutations from Standard milo, such as, for example, University Farm Select and Heileman. Its place of origin is also unknown, and since there are apparently several strains now in cultivation it is possible that it may have two or more independent origins. Creighton[19] states that it seems to have first appeared in the Salt River Valley of Arizona in about 1910, and to have been sent from there to the Imperial Valley in California. Mr. J. C. Archias, of the Cuff-Archias Seed Company of Brawley, in the Imperial Valley, is of the opinion that the variety was selected from a field of Single Dwarf milo by a Japanese farmer named Miyama, and states that his first acquaintance with the variety was on Miyama's ranch near Brawley, in about 1918. Unfortunately, our efforts to locate the said Miyama have proven fruitless. A letter from C. C. Deane, now of Los Angeles, California, states that he secured 40 pounds of seed of Double Dwarf Yellow milo from the Nicholl-Loomis Grain Company, Brawley, California, and grew it in the Imperial Valley in 1918. Double Dwarf milo first came to the attention of the writer in 1921, when a nonuniform and badly mixed field was observed on the farm of Prof. S. S. Rogers near Davis, California. The seed for this planting was obtained by Rogers from a seed dealer named O. B. Crary, in Calipatria, Imperial Valley, in 1920. Crary recalls the transaction but has no knowledge of the source of the seed. Twenty heads were selected from this field and grown in separate rows on the Experiment Station plots at Davis in 1922, and seed of a uniform strain was first distributed from there in the fall of 1924. Seed was sent to the University of California Imperial

[19] Creighton, D. E. Formerly Assistant Farm Advisor of Imperial County. Personal communication.

Valley Experiment Station at Meloland in 1923, where it was grown for the first time in 1924, and this was also the first time that Double Dwarf milo had been seen in the Imperial Valley by officials of that station. Following this there was a rapid distribution from both Davis and Meloland, and later from the U. S. Cotton Field Station at Shafter, Kern County, California, with the result that by 1930 it had almost completely replaced all other milo varieties in commercial plantings throughout the state.

The variety differs in no important visible respects from other strains or varieties of Yellow milo except as to height, and in this it varies from 2½ to 3½ feet under conditions which cause Single Dwarf milo to reach 4 to 6 feet, and Standard milo 6 to 8 feet. This characteristic has given it a marked advantage over other milos for combine-harvesting and has also eliminated entirely the problem of lodging. In yield tests conducted in rows spaced 36 inches apart it has proven only slightly less productive than Single Dwarf milo, but under favorable conditions this spacing is too great, and with the 26 to 32-inch spacing now frequently practiced Double Dwarf milo is thought to be the equal of Single Dwarf milo in productivity.

White and Brown Durra (Egyptian Corn).—White-seeded durra varieties of the flat-seed type now grown in California have been under cultivation since ancient times in Turkestan, Arabia, and Egypt, and have probably been introduced from these regions into the United States upon several occasions since as early as 1836.[20] Round-seeded varieties of White durra have also been introduced from India. There are many references to durra or dourah in the agricultural press of the United States from 1855 onward, but since these names are synonymous with sorghum in Egypt, and since they have been applied to other types of sorghum in this country, it has been difficult to trace the earlier history of the crop in America with accuracy. The first definite reference to durra or Egyptian corn, as we know it in California today, appeared in 1874,[21] in which it is stated that Mr. R. J. Trumbull of San Rafael had imported the seed from Egypt and grown it in his nursery that year. Wickson,[22] however, is of the opinion that still earlier importations had been made into California, and presents several citations from the press of the state in support of this contention. In all cases, however, there is

[20] Unsigned letter to New York Farmers' Club in the American Agriculturalist 3:7. 1844. Also: Sorsby, N. T. Indian millet or dourah corn. *In* report of the Commissioner of Patents for the year 1854. Agriculture p. 160–162. 1855.

[21] Egyptian corn. Unsigned editorial. Pacific Rural Press 8:177. 1874.

[22] Wickson, E. J. Senator Sorghum, a California pioneer. Pacific Rural Press 43: 289–301. 1917.

no sufficient description of the plant to establish its identity with certainty. At all events, the crop was little known in California prior to Trumbull's introduction and did not assume economic importance until it became identified with the rapidly developing irrigation districts of the San Joaquin Valley subsequent to 1874. From this time onward there is frequent reference in the press to its adaptation, productiveness, and utility in the interior valleys of California, and it apparently increased in acreage until the coming of Yellow milo, in about 1890, when it began to diminish in popularity in competition with that more suitable crop. Both the White and Brown durra (Egyptian corn) varieties apparently were introduced into California simultaneously. Following the Trumbull introduction in 1874 the crop soon reached the Great Plains from California and became popular in Kansas during the late eighties and early nineties, and was grown at the Kansas Agricultural Experiment Station in 1889 under the name Egyptian Rice Corn and at other plains' experiment stations soon thereafter. Hundreds of durra introductions have been grown on experiment stations in this country since 1900, but they have never compared favorably with kafir and milo, except in the Sacramento Valley of California.

The Brown and White varieties are much alike except as to seed color, and this is the chief point of distinction between them. Both produce tall, irregular plants, 4 to 8 feet in height, under favorable conditions; both stool sparsely, and produce comparatively dry and leafless stalks. The heads are large, compact, and of ovoid form. The seeds are large, strongly flattened, and easily separated from the heads at maturity. The plants possess little forage value, but the seed of the White variety is the most valued of all grain sorghums by California poultrymen. These varieties are approximately as productive as milo, but are seldom as profitable because of their tendency to shatter and lodge, their susceptibility to bird damage, and their high harvesting cost. Their continued cultivation in California has been chiefly insured, first by their early maturity, which gives them an advantage in the northern districts and in dry situations, and second by the esteem in which they are held by poultrymen, which in the case of the White durra causes it to be sold at a premium over milo.

Dwarf White Durra (*Dwarf White Egyptian Corn*).—This strain (fig. 3) originated as a selection from a field of Standard White durra made by the Hoefling Brothers of Chico, California, in 1925, and after three years of selection and testing was first distributed for seed in 1929 under the name of Hoefling's Curly Leaf or Superior strain of White Gyp. Several field plantings were made that year in both the Sacramento

and San Joaquin Valleys and these created so favorable an impression that a large amount was acquired by a Stockton grain dealer and distributed widely for seed in the 1930 season. The result of this was that in that year this variety exceeded Standard White and Brown durra (Standard White and Brown Egyptian corn) in acreage and ranked second only to Double Dwarf milo as the most important grain sorghum in California. Since that time the acreage has declined in favor of Double Dwarf milo, but it is still extensively grown, particularly in the

Fig. 3.—Dwarf and Standard varieties of White durra (White Egyptian corn). The double row in the center and the block at the left are Dwarf. The block at the right is Standard.

northern Sacramento Valley, and appears to have permanently replaced the tall-growing parent stock just as the dwarf milos have replaced Standard milo.

In all visible characters except height and leaf color, Dwarf White durra is closely similar to its parent Standard White durra. In color the midrib of the leaf is yellowish instead of white as in the parent form. Under favorable conditions it attains a uniform height of only about 4 feet. This characteristic adapts it satisfactorily to combine-harvesting and eliminates entirely the difficulty from lodging. In yielding capacity it is not inferior to the parent form but in order to insure maximum yields must be more closely spaced, or in rows 26 to 32 inches apart under conditions calling for from 34 to 40 inches for Standard White durra. In recent trials at Sacaton, Arizona, and at Logan, Utah, it has not compared favorably with the milo varieties in point of yield. Its chief value in California lies in its early maturity, which gives it an

advantage over milo in northern districts and in dry situations. Its dwarf habit and nearly erect heads adapt it satisfactorily to the use of the combine.

VARIETIES OF MINOR IMPORTANCE

Standard White Milo.—This variety has been thought to have originated as a recessive mutation from Standard Yellow milo somewhere in northwestern Texas prior to 1910, but it may possibly be a direct importation from Egypt, where a very similar or identical variety has long been in cultivation. It is similar in all respects to Standard Yellow milo except in color of seed, which is cream instead of yellow. It has been tested and occasionally grown in California, but possesses nothing to recommend it over other varieties and is of no commercial importance.

Dwarf White Milo.—This variety originated among farmers in northern Texas in about 1915 and is apparently a double recessive which may have originated by recombination from a cross between Standard White milo and Dwarf Yellow milo. It is much like Heileman and other single dwarf strains of Yellow milo in all respects except seed color, which is creamy. It has been occasionally grown but is of no commercial importance in California.

Double Dwarf White Milo.—This form originated at the Lubbock Experiment Station in Texas, in 1925, as a double recessive from a hybrid between Dwarf White and Double Dwarf Yellow milo. It is of no importance in California.

Early White Milo (Sixty-Day or Ninety-Day White Milo).—This is a distinct form of the above-mentioned white milos which is somewhat earlier in maturity and between the single dwarf and standard types in height. This variety or a strain of it has become popular in the vicinity of Lubbock, Texas, where it is usually called Sweet or Sugar milo. It is of no commercial importance in California.

The Feteritas.—Standard feterita was introduced into the United States from Anglo-Egyptian Sudan in 1901, and again in 1906. It came to California soon after 1906 and was produced to a limited extent from about 1910 until 1922, but with the appearance of Heileman and other improved dwarf strains of milo in about 1922 its cultivation practically ceased. It proved comparable to the milos in productiveness in California but was chiefly objected to because of its tall growth, which was an obstacle to combine-harvesting. Three strains, known respectively as Spur, Dwarf, and T. S. No. 2840 (F. C. 811), have been produced in Texas, but none of these have proven well adapted to California conditions.

Hegari.—Hegari was first grown in the United States at Chillicothe, Texas, from seed imported from Africa in 1907, under S. P. I. No. 22326, and it has been much improved by selection since that time. The plant varies from 3 to 5 feet in height, produces erect kafir-like heads, with comparatively large, chalky-white seeds, and in California matures late in the season. It stands up well under irrigation and produces an abundance of good forage. For these reasons it has been extensively planted in conjunction with stock-raising in Texas, Oklahoma, and Arizona, and to a limited extent in the Imperial Valley of California. Because of its late maturity and bulky, irregular growth, it has not been popular as a grain crop in any part of California.

Darso.—This variety appears to be a milo-sorgo hybrid. The fact that it has recently been found to be completely susceptible to the new milo root-and-stock rot disease occurring in the southern Great Plains area—a disease peculiar to milo and milo hybrids—indicates, though not positively, that it is a milo-sorgo hybrid rather than a kafir-sorgo hybrid, as heretofore generally thought. It was first observed under cultivation in central Oklahoma and was distributed by the Oklahoma experiment station in about 1914. The plant is leafy and juicy and possesses good forage value, but its semi-erect habit, late maturity, and comparatively low grain yield have made it unpopular as a grain crop in California. It is chiefly grown in conjunction with stock-farming in Oklahoma and eastern Texas, and has occasionally appeared in the Imperial Valley of California.

Kafir.—Kafir is a diverse group of grain-sorghum varieties native to the Sudan and Natal districts of Africa. Certain forms of this were brought to the West Indies from western Sudan as a food on slave ships at an early period, but the dominant varieties in the United States today are of the Natal type. It began to attract attention in the United States as early as 1876, and has since come to fill a place of great importance in the farm economy of the arid mid-western United States. It is drouth-resistant and produces both grain and forage of good quality, and has therefore fitted well into the system of general farming with livestock in the region mentioned. It has been introduced into California upon many occasions but has not proven well adapted in this state. In comparative trials in various California localities it has proven considerably less productive of grain than milo or durra (Egyptian corn) and less productive of forage than sorgo. The different varieties vary considerably in their characteristics and adaptations, but none of them have yet shown economic promise in California.

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